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The Stellar Imager (SI) "Vision Mission"

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The Stellar Imager (SI) is a "Vision Mission" in the Sun-Earth Connection (SEC) NASA Roadmap, conceived for the purpose of understanding the effects of stellar magnetic fields, the dynamos that generate them, and the internal structure and dynamics of the stars in which they exist. The ultimate goal is to achieve the best possible forecasting of solar/stellar activity and its impact on life in the Universe. The science goals of SI require an ultra-high angular resolution, at ultraviolet wavelengths, on the order of 100 micro-arcsec and baselines on the order of 0.5 km. These requirements call for a large, multi-spacecraft (>20) imaging interferometer, utilizing precision formation flying in a stable environment, such as in a Lissajous orbit around the Sun-Earth L2 point. In this paper, we present an update on the ongoing SI mission concept and technology development studies.

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I. Introduction

The Sun is a variable star that nurtures the only known life forms in the Universe. Understanding the long-term solar variability and its effects on the Earth's magnetosphere and atmosphere is the key to understanding the environment in which life began, as well as the prospects for its future existence and preservation. Solar activity levels change significantly, both up and down, and can tremendously affect the Earth's climate. For example, historical records show that solar activity decreased for > 50 years during the 17th century when Earth experienced the Little Ice Age. On the other hand, a sustained increase of activity—such as happened during the 12th century (the Grand Maximum)—may cause a warm spell with an associated increase in the frequency of space storms and ultraviolet radiation that is harmful to life on Earth. Recently, we have begun to realize the extent to which the short-term solar variability affects everyday life and society. It affects the technology upon which we are becoming ever more reliant: eruptions on the Sun interrupt communications, affect navigation systems, cause radiation harmful to astronauts and airline passengers, destroy satellites, and occasionally push power grids to fail. The causes of the long- and short-term solar variability are not yet understood. *It is clear, however, that the activity is governed by the magnetic field created in the depths of Sun by a process that we call the dynamo*[1]. Identifying the fundamental mechanisms of solar variability is crucial for the validation of dynamo models. Understanding the manner in which it affects the Earth's environment is an essential prerequisite to educating the public and guiding policy decisions.

The dynamo is one of the deepest mysteries in astrophysics and there is at present no model for the dynamo that can be used to forecast the Sun's activity on time-scales of months to decades.

What we do know currently is that in Solar-type stars the dynamo operates in the outermost 200,000 km of the stellar interior, in and just below the convective envelope, and that it manifests itself in the surface patterns formed by the magnetic field. These structures, observable in bright emission lines like C IV λ1550, provide the only readily accessible information on the dynamo properties and are dependent on stellar parameters including convection, differential rotation and meridional circulation. Direct imaging of these structures and their evolution over extended periods on multiple stars using the proposed Stellar Imager (SI) is the only way to obtain the required information on stellar dynamos, and to produce and test on a relatively short timescale robust models for forecasting solar activity.

SI is envisioned as an ultraviolet-optical aperture-synthesis imager with numerous, sparsely-distributed apertures each at least one meter in size and forming baselines up to 500 m, and a central hub with focal-plane instrumentation that allows spectrophotometry in passbands as narrow as a few Angstroms up to hundreds of Angstroms. Initial sets of science goals and performance requirements have been formulated, along with a strawman observatory design[2], and are available at http://hires.gsfc.nasa.gov/~si . Members of the SI Concept Development Team have carried out early architecture studies, established a ground-based experiment (the Fizeau Interferometer Testbed, the FIT) to investigate closed-loop control of a many-element sparse aperture system, and written a simulator (SISIM by R. Allen/J. Rajagopal at STScI). The STAR9 Testbed at LMATC also provides a ground test environment for wavefront sensing and control of multiple apertures. Figure 1 shows an artist's concept of one of our initial strawman designs, the Fizeau Interferometer option.

Stellar Imager is on the strategic path of NASA Origins and ESA interferometry missions. It is a stepping stone towards crucial technology: SI is comparable in complexity to the Terrestrial Planet Finder (TPF)/Darwin nulling-IR-interferometers, and it may serve as a useful pathfinder for the Planet Imager (PI). SI addresses science goals of three NASA Science Mission Directorate Themes: understand why the Sun varies (Sun-Earth Connection), understand the origin of stars, planetary systems, and life (Origins), understand the structure and evolution of stars (Structure and Evolution of the Universe). It is complementary to the planetary imaging interferometers. TPF/Darwin, and PI null the stellar light to find and image planets, while SI images the central star to study the effects of that star on the habitability of those planets. TPF/Darwin, SI, and PI together will provide complete views of other solar systems.

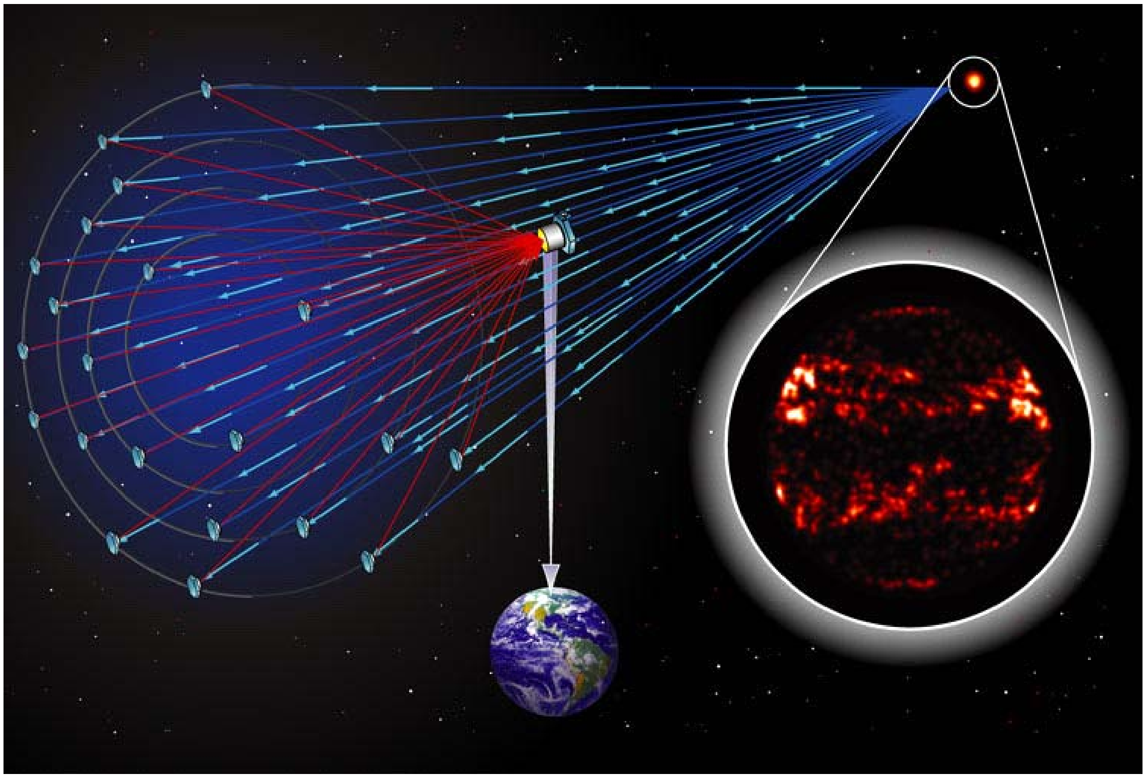

Figure 1: An artist's concept of the current "Strawman" architecture for the SI. A simulated C IV (λ1550) SI image of a Sun-like star at 4pc is shown in the lower right.

II. Science Goals and Mission Requirements

A. Primary Science Goals: Targeting Dynamos and Sun-Earth Connection

Models of the solar dynamo are in their infancy. Progress in solar dynamo modeling has been driven uniquely by observational constraints – substantial further progress is dependent on new activity imaging of stars significantly different from the Sun. Rigorous testing of such models would require observations of solar magnetic structures obtained over numerous solar cycles, and probably through Maunder-type minima and Grand-type maxima as well, to collect data on the many different aspects of solar activity and their evolution. This may require several centuries. The proposed SI mission will accelerate this process significantly by observing the activity in a large sample of stars in a short period of only a few years.

The primary goal of the proposed Stellar Imaging mission is to study in the UV/optical the spatial and temporal stellar activity patterns in a sample of stars covering a broad range of activity level with the unprecedented angular resolution of 0.1 milliarcsecond (mas), in order to:

- understand the underlying dynamo process(es) to enable improved forecasting of stellar and solar activity on timescales of days to centuries
- understand the effects of stellar magnetic activity on the formation of stars and planetary systems, and on the habitability of planets, especially those found by missions such as Kepler, TPF/Darwin, and imaged by PI; *thereby understand the impact of stellar magnetic activity on life in the Universe*
- enable spatially resolved astero-seismology to measure *internal stellar structure and rotation profile with depth* and their relationship to the dynamo.

The forecasting of solar activity and its potential impact on the terrestrial environment requires a successful quantitatively predictive dynamo model. Such a model is (so far) elusive, even for the well-observed Sun. In part, this is because the Sun provides only a single data point in the parameters that control the dynamo (e.g., mass, rotation, age, metallicity), and because we have yet to observe the Sun with modern instruments at the extrema of its activity. To understand the dynamo, we need to know how magnetic fields are generated and behave in different physical conditions. We must therefore observe other stars to establish how mass, rotation, luminosity, and age affect the *patterns of activity*. The measurements needed to characterize the patterns of activity are given in the following section.

Like our nearest star, most cool stars (i.e., those with non-negligible subsurface convective zones) display evidence of surface magnetism. For example, the analysis of the disk-integrated Ca II H & K flux measurements from the large database at Mount Wilson Observatory, encompassing cool stars from the lower main sequence through supergiants[3,4], reveals similarities to and differences from the Sun's surface magnetism. Several lower main sequence stars reveal surprising persistence of surface features -- much longer than the months duration typical of the Sun's active regions[5,6].

The magnetic fields of the Sun and other cool stars are generated by a magneto-hydrodynamic dynamo (see early developments[7,8,9,10] and a recent review[11] and references therein). The dynamo process is highly complex, occurring over a wide range of physical conditions and scales within the stellar interior. Consequently, models make numerous approximations and simplifications, often representing feedback processes by *ad hoc* functions that are more of heuristic value than representative of real stellar conditions. Knowledge of the patterns of stellar magnetic fields, and of their evolution with time, is essential to the development of a reliable dynamo model consistent with the physical processes that it incorporates. *That knowledge can be derived only by imaging the patterns of activity on stellar surfaces as a function of basic stellar parameters and stellar age*.

The quantitative study of the evolution of surface magnetic structures in stars similar to the Sun in terms of mass and age will reveal the full spectrum of variability that can be expected from the solar dynamo. Imaging activity on other stars will provide the first information on the temporal and spatial scales for activity phenomena on other stars, and on the details of processes like differential rotation and meridional advection that are thought of as the driving forces behind a stellar dynamo. That information will help us develop and test a model for the dynamo with forecasting value, and at the same time provide insight to conditions on the past and future Sun that can influence the habitability on our planet Earth.

Observations of magnetically active stars and their surroundings will also provide us with an indirect view of the Sun through time[12], from its formation in a molecular cloud, through its phase of decaying activity, to its ultimate death beyond the red-giant phase, during which the Sun will swell to about the size of the Earth's orbit (Figure 2).

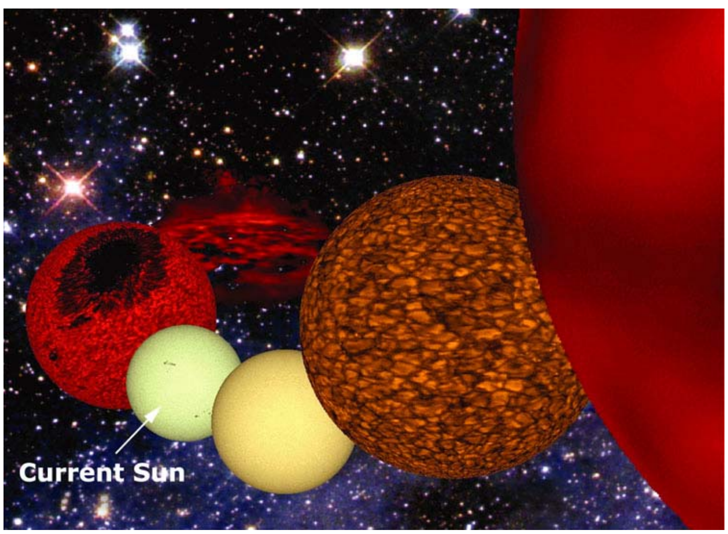

Figure 2: An illustration of the evolution of the Sun over a period of 10 billion years, from a protostellar disk to a red giant star. Magnetic activity plays a role from the formation of the star and its planetary system through most of its main sequence life.

SI imaging of stars in short-period (i.e., days to months) active binary systems will produce dramatically detailed maps of surface activity that will probe dynamo processes at the most extreme levels of stellar activity. The complex magnetic topology within active binaries will likely produce not only surface active region UV emission but also extended emission related to global fields with sizes similar to those of the binary orbits. The angular scales of the stellar disks and binary orbits are well matched to the angular resolution of SI. The large UV fluxes of these systems will allow high signal-to-noise imaging. The atmospheres of these binaries are highly dynamic with frequent large-scale flares; SI has the potential to image flare-related mass ejections from these stars[13]. Although the clearest manifestations of the dynamo processes are on the surface, *a full understanding of the dynamo also requires a knowledge of the underlying layers* that can be only achieved using asteroseismology.

The incredible success of helioseismology is based on the precise characterization of the frequencies of the solar acoustic spectrum. Today, the solar structure is known with a precision better than 0.1%, while the solar rotation rate and its variation with the solar cycle is measured with a 0.5% accuracy, over most of the solar interior -- with the exception of the regions very near the solar core and very close to the poles. Helioseismic constraints on the solar *standard model* have been so severe that the only way to solve the so-called *neutrino problem* was to revisit fundamental assumptions of elementary particle physics.

For Sun-like stars, we aim to measure the so-called p (pressure) modes, which are resonant acoustic waves trapped in the stellar interior as a result of the sound speed stratification. They can be observed at the surface as velocity or (as intended with SI) intensity fluctuations (as a function of space and time) with periods around 5 min for the Sun. The precise value of each mode frequency is determined by the physical properties (temperature and density), the chemical composition and the dynamical state (velocity flows) of the domain sampled by that mode. Intense efforts on the detection of p modes on solar-like stars from the ground have yielded positive identification for only a few bright stars, observed with large telescopes. In the near future several space missions (e.g. MOST, COROT, and Kepler) hold the promise for analyzing acoustic oscillations for a larger sample of stars. However, in all these cases the stellar disks are not resolved, and hence only the lowest-degree modes (i.e., $0 \leq \boldsymbol{l} \leq 4$) can be detected. These modes provide valuable information on the star, but are only a very small subset of the modes observable when the stellar disk is resolved.

The SI will provide access to many higher degree modes from observations of intensity fluctuations as function of location on the stellar disk. These observations will provide not just the global averages of the previous missions but actual depth resolution for both structure and rotation. As in the solar case, these higher-degree modes will provide, in particular, detailed resolution of the structure and rotation of the layers near the base of the stellar convection zone, of crucial importance to the operation of the stellar dynamo; in particular, they may reveal the presence of a region of strong rotational shear as found in the solar tachocline.

B. Additional Science Goals

The performance requirements on SI set by the primary scientific goals, especially the unprecedented angular resolution in the UV, present a wide variety of opportunities for fundamental advancement in other areas of astrophysics as well. For example, the SI could enable us to study the close-in structure of supernovae and their remnants, hot polar winds and non-radial pulsations of Be-stars, and it will resolve the components of many close binaries, yielding determinations of fundamental stellar parameters. Space limitation precludes describing all of the numerous scientific topics that could be addressed using the unique capabilities of SI in this paper, but further information on these additional science topics is available[14].

C. Scientific Requirements for the Mission

The primary science goals require that SI enable:

- ***imaging*** of stellar surface structures to detect and monitor the evolution of active regions,
- ***asteroseismology*** to obtain information on the sub-surface layers.

Direct imaging *is the only way to obtain necessary information on the dynamo patterns for stars with Sun-like activity*. Alternative methods, that may offer limited information on spatial patterns on much more active stars, necessarily fail for a Sun-like star. Rotationally-induced Doppler shifts in such stars are too small compared to the line width to allow Zeeman-Doppler imaging. The activity level is insufficient to lead to significant spectral changes associated with magnetic line splitting. Rotational modulation measurements are inherently subject to deconvolution limitations that leave substantial ambiguities in the latitude distributions, locations and sizes of spots, and cannot be used to understand the facular contributions in quiet regions that are governed by field dispersal and differential rotation.

Direct imaging must be done in the UV for a number of reasons. The dark starspots in the visible-light photosphere are small in most stars and have low contrast with the surrounding bright stellar surface, making them difficult to detect with the moderate number of resolution elements attainable on distant stars, even with a "Vision Mission" such as SI. However, the bright spots seen in UV chromospheric and transition-layer emission (eg., Mg II h&k, C IV λ1550), from regions of enhanced magnetic activity above the surface wherever it is penetrated by strong magnetic fields from regions below the surface, are both larger and exhibit higher contrast with the background photosphere. This larger size and increased contrast are thus critical to detection and tracking of the signatures of surface magnetic activity. Observations of the optical Ca II H&K lines cannot be used for this imaging due to the substantial background contribution from non-magnetic flux present at those wavelengths. A space-based UV interferometer with a 500 m baseline provides the angular resolution needed to resolve and image stellar magnetic field structures and for monitoring the evolution of that activity with time.

To answer the questions posted in Section IIA and to achieve the primary science goals, the mission must meet the measurement requirements shown in Table 1.

Modest integration times (~hours to days) are both sufficient (given the brightness of the targets) and required to avoid smearing of images due to rotation, proper motions, and activity evolution. The asteroseismology requires even shorter integration times (~minutes to hours) – these exposures will thus be done in broadband continuum optical wavelengths to ensure adequate fluxes and photometric accuracy for measuring non-radial resonant waves on the short timescales required. Flexible interferometer configurations are required for both surface and sub-surface image synthesis. Although long mission life and numerous images of many stars (demanding on fuel requirements) are difficult simultaneous requirements, previous GSFC Integrated Mission Design Center studies indicate several possible viable solutions which are under further study.

Table 1: Measurement Requirements for SI

Imaging stellar activity using emission from the outer atmosphere
Image in UV emission lines a substantial sample (e.g., most of the 49 nearby stellar systems within 10 pc with A7-K5 main-sequence stars, plus a sample of more distant evolved stars) of stars representing a broad range in magnetic activity. Ensure at least 1000 total pixels (~50,000 km resolution) covering the disk on a Sun-like star at 4 pc; requires a baseline of 500m.
Construct images within ~1% of the stellar rotation period, i.e. ~6 hr for a Sun-like star; requires efficient reconfiguration and/or a large number of interferometer components (faster rotation requires more components).
Compile at least ~20 images within one stellar rotation; requires optimized target lists and efficient repointing.
Measure sizes, lifetimes, and emergence patterns of stellar active regions, surface differential rotation, field dispersal by convection and meridional circulation.
Revisit stars at 3-6 month intervals spanning ~10 yrs; requires a long operational life, and preferably replacable component spacecraft.
Imaging stellar interiors with asteroseismic techniques
Enable detection of low to intermediate degree non-radial modes to measure internal stellar structure and rotation vs. depth.
Achieve 30-100 resolution elements on stellar disks with 1 min. cadence, in a broad passband in the optical; requires 9 optical elements, with meter-class collecting areas, aligned perpendicular to stellar rotation axis.
Continuous observations for approximately one rotation, with duty cycle better than ~90%; requires stable environment.

III. The "Vision Mission" Concept Study

Recently, the Stellar Imager was competitively selected via the "Vision Mission" NASA Research Announcement (NRA) for further concept development. NASA-GSFC has brought together a diverse team of industry, university, and astronomical institutes to partner in this study, including Lockheed Martin Advanced Technology Center, Ball Aerospace & Technologies Corp., Smithsonian Astrophysical Observatory, the Space Telescope Science Institute, the University of Colorado, the University of Denver, the State University of New York at Stonybrook, Seabrook Engineering, Sigma Space Corporation, the Astrophysical Institute Potsdam, University of Aarhus, Kiepenheuer Institute, Stanford University, the Naval Research Laboratory, Eureka Scientific, Catholic University of America, Arizona State University, and the University of Texas at Arlington. The individual investigators include:

- **GSFC**: K.Carpenter, R. Lyon, W. Danchi, J. Leitner, L. Mazzuca, C. Bowers, A. Liu , R. Moe, J. Camp, B. Woodgate, S. Neff, G. Sonneborn, R. Kimble
- **LMATC:** K. Schrijver, D. Chenette
- **JPL**: N. Murphy, M. Shao, F. Hadaegh, J. Breckinridge, G. Blackwood, P. Liewer, M. Velli
- **BATC**: S. Kilston, C. Noecker, R. Linfield, M. Lieber, R. Reinert
- **SAO**: M. Karovska, J. Phillips, S. Korzennik , W. Soon, D. Ragozzine, L. Watson, S. Baliunas, A. Dupree, M. Elvis, N. Evans, P. Kaaret, L. Hartman, E. Lorenzini, M. Marengo, D. Sasselov, E. Schlegel, D. Steegs, R. Reasenberg
- **CU**: A. Brown, G. Harper, F. Day, J. Linsky, T. Ayres
- **SUNY:** F. Walter, **SE**: D.Mozurkewich**, Sigma:** J. Marzouk, **STScI:** R. Allen
- **AIP**: K. Strassmeier**, KI**: O. Vander Luhe**, U. Aarhus**: J. Christensen-Dalsgaard
- **Stanford U.**: J. Schou, P. Scherrer, **ASU**: J. Morse, **CUA**: F. Bruhweiler, **UTA**: M Cuntz
- **UD**: R. Stencel, **Eureka**: C. Grady, **NRL**: T. Armstrong, **UMD**: L. Mundy

This team is refining the science goals and requirements of the mission and examining architectures that can be evolved, for example from a modest "Phase I" facility (e.g., 25-50 m baseline, 2-5 elements) to a full implementation of 20-30 elements with 250-500 m or longer baselines ("Phase II", the full "Vision Mission"). Phase I would provide more than an order of magnitude better angular resolution than HST, while Phase II would provide more than two orders of magnitude better resolution than HST. The study will explore alternative architectures for the mission and their various strengths, weaknesses, and technological needs; perform selected major technical studies; and select the most promising architecture(s) for detailed further study. It will also produce an improved technology roadmap, including a requirements flow-down and systems engineering plan, derive detailed scenarios for deployment and operations, and investigate the possible roles of astronauts and/or robots in the construction or servicing of the facility.

Although the formal "Vision Mission" Study is in progress as this manuscript is being written, many of the basic architecture concepts and technology requirements are understood and are described in the following section. These will, of course, all be refined and/or expanded during the Vision Study.

IV. Initial Architectural Concepts and Technology Requirements

A. Strawman Full-Mission Concept

The strawman architecture for SI is driven by the science goals and associated performance requirements. The flowdown of these goals and requirements to the engineering and technology implications is shown in Figure 2.

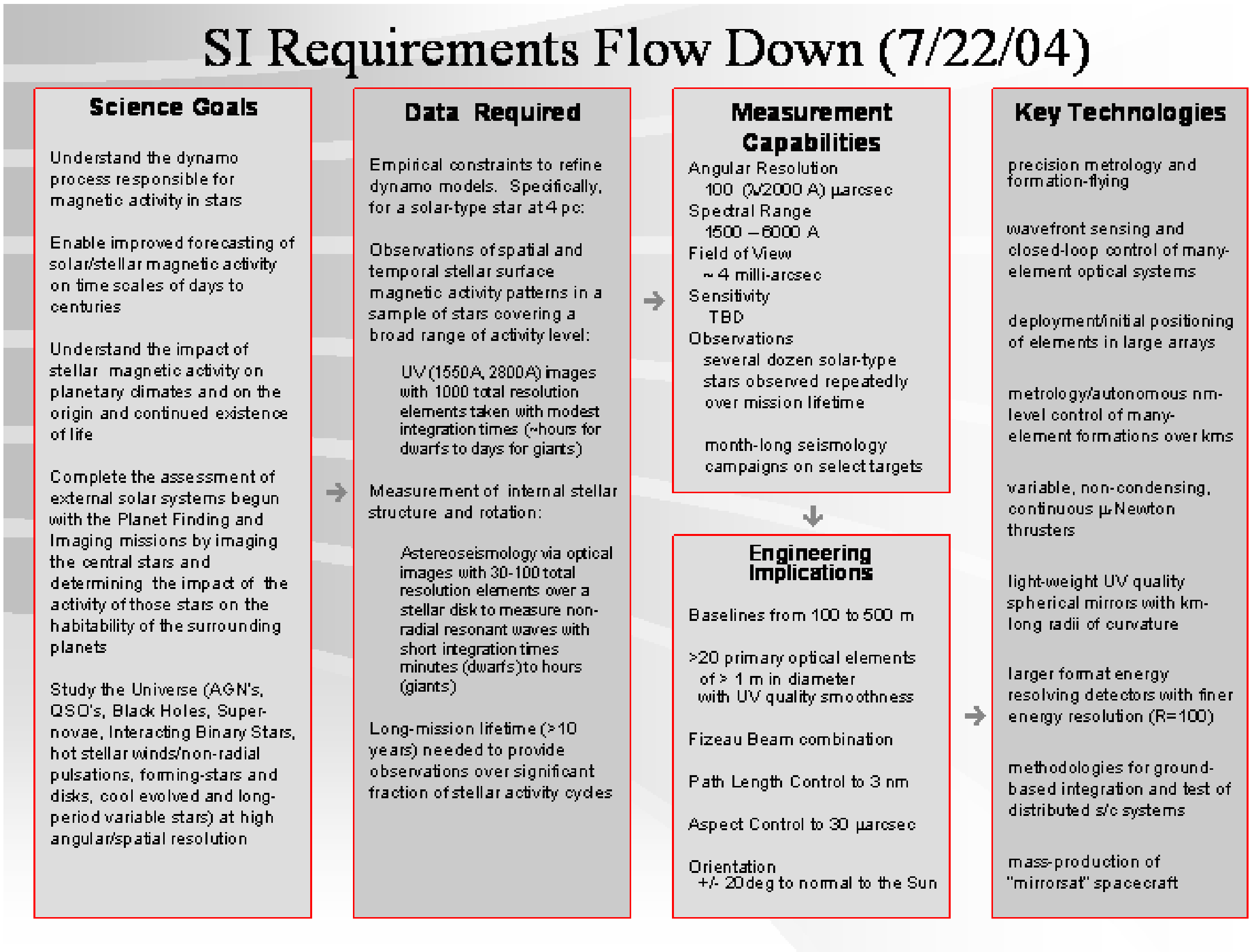

Figure 2: The requirements "flowdown" from SI Science Goals to Engineering and Technology Needs

This flowdown leads to the current strawman architecture concept for *Stellar Imager (SI)*: a 0.5 km diameter, space-based, UV-optical Fizeau Interferometer composed of a reconfigurable array of 20 - 30 one-meter-class spherical array elements on small satellites ("mirrorsats"). Those elements direct light to an image-plane beam combination facility in a hub at the prime focus, as shown in Figures 1 and 3. A view of the primary array from the hub is shown in Figure 4.

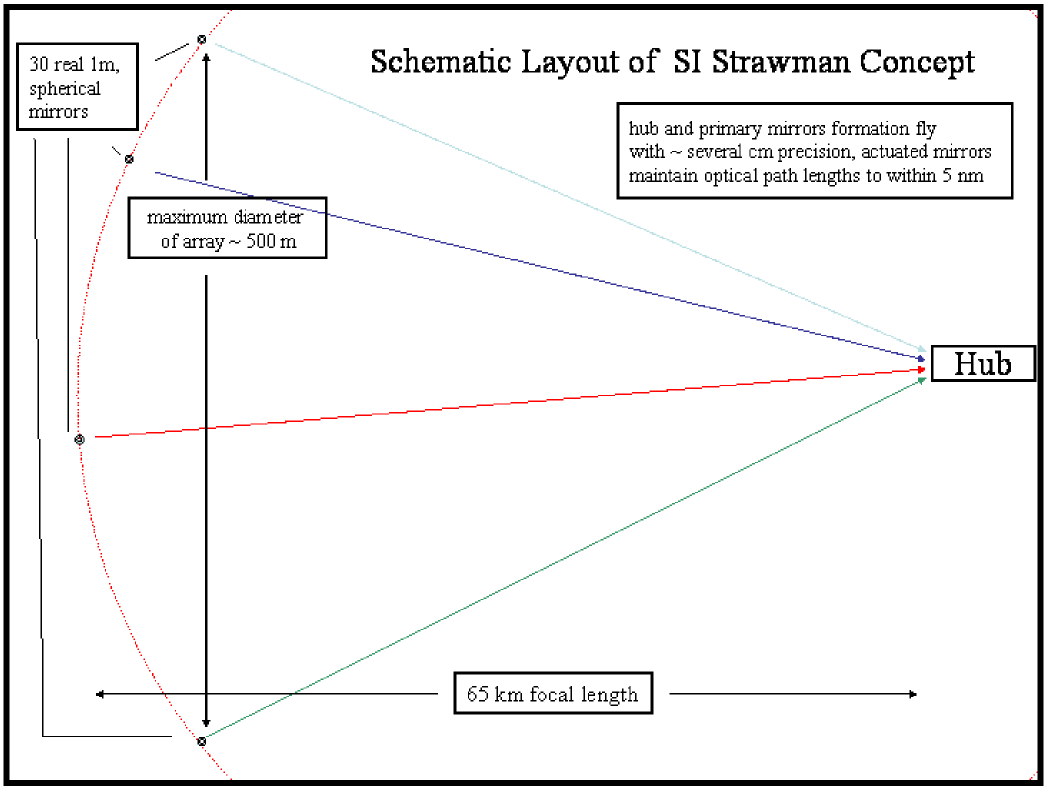

Figure 3: A cross-sectional view of the strawman SI design

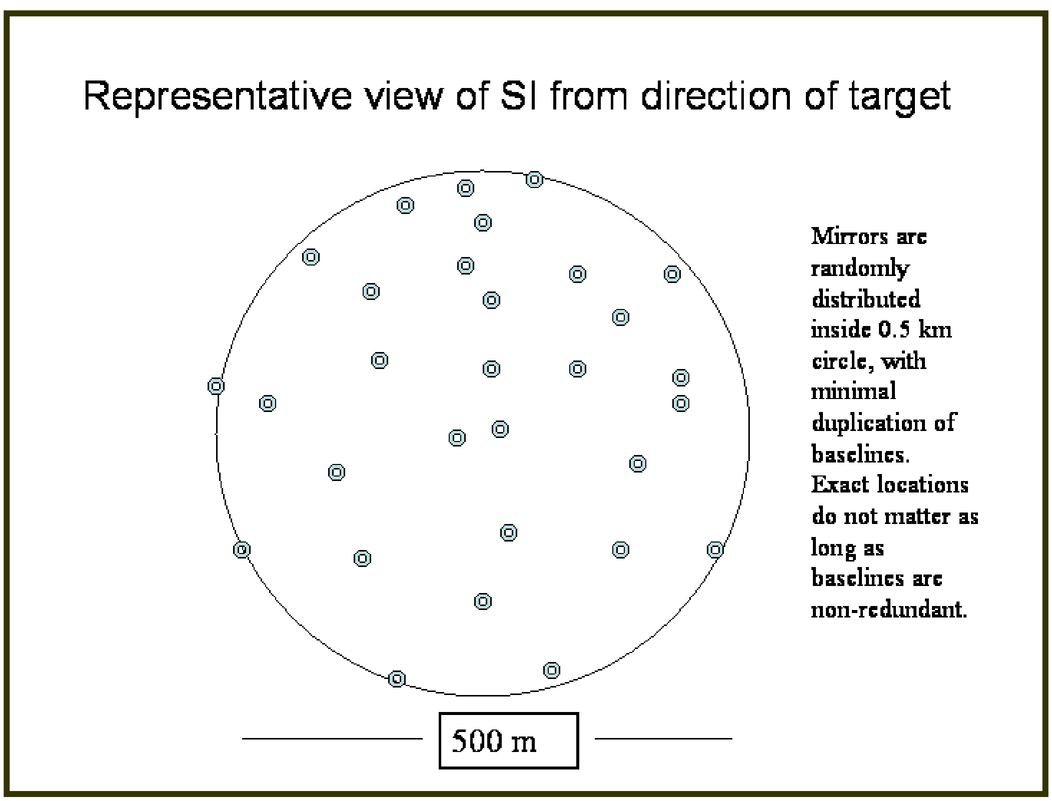

Figure 4: A view of the primary array from the hub, in the strawman SI design.

This design would provide: an angular resolution of 60 and 120 micro-arcsec at λ1550 and λ2800, ~1000 pixels of resolution over the surface of nearby dwarf stars, observations in several-Angstrom UV pass-bands around, e.g., C IV (100,000 K) and Mg II h&k (10,000 K), and broadband observations in the near-UV or optical continuum (formed at 3,000-10,000 K). It is designed as a long-term mission with a requirement of a 6-year lifetime and a goal of 10-20 years, to allow the study of significant portions of stellar magnetic activity cycles. Individual telescopes and the central hub are designed to be refurbished or replaced as needed to support this long mission lifetime.

SI would be located in a Lissajous orbit around the sun-earth L2 point. It cannot be in low-earth orbit because the strong gravity gradient there would not permit precise formation flying (in addition to potential scattered light difficulties). An earth-trailing orbit is not desirable since replacement of failed array elements and addition of improved (larger) array elements would not be possible. L2 has both a small and very well characterized gravity gradient to permit precise formation flying and should be accessible in the 2015-2020 time frame for servicing and upgrade by robotic and/or manned missions.

A Fizeau configuration is preferred over a Michelson design because it simplifies the beam-combination station tremendously (and also minimizing the number of reflections in the system, which is critical to maintaining UV sensitivity) and thus substantially lowers the cost of using many array elements. The use of many array elements enables quick acquisition of data to support imaging of transient stellar surface features (intrinsic variations, plus rotational and proper-motion-induced blurring) and high-time resolution asteroseismology, and it minimizes the number of re-configurations of the array needed to obtain the required number of baselines to ensure the desired image quality (number of baselines ~ number of pixels). Other benefits include low consumption of propellant enabling the desired long-duration mission, minimizing overhead time for reconfigurations, maximizing observing efficiency and the ability to image time-dependent phenomena.

The images that could be obtained with the strawman mission design are illustrated in Figure 5 for various numbers of elements and re-configuration strategies.

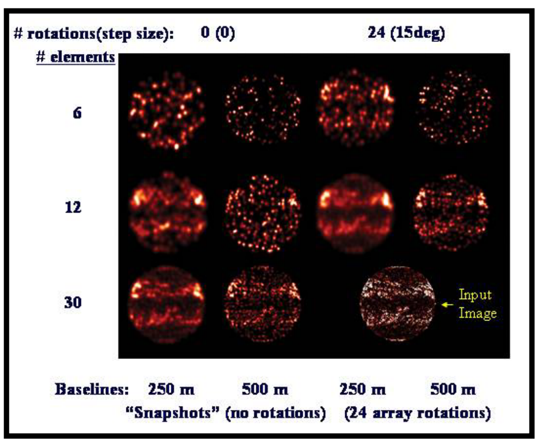

Figure 5: These simulations were computed with SIsim, developed by R. Allen and J. Rajagopal (STScI), assuming 250 (first and third columns) and 500 (second and fourth columns) meter maximum baseline arrays. The first two rows assume Y-shaped configurations with 6 and 12 elements, respectively. The last two columns of those rows assume that the array is rotated 24 times (15 degree motions) to acquire sufficient Fourier UV-plane sampling. The 1st two images in the last row assume 30 elements arranged in a low-redundancy "Golomb rectangle"[15]. The first two columns in all cases show "snapshots" taken without rotating the arrays. The image in the lower right is the input image.

This figure shows that 30 static elements appear to be sufficient to adequately synthesize this particular stellar image. The 435 baselines provided by the static 30-element array work well because only about half of the 1000 pixels in the image are truly filled. If all the image pixels were filled (or a large number of the remaining pixels), then a second configuration of the array (e.g., a 90-degree rotation) would be necessary for sufficient sampling. Alternatively, fewer elements can be used with a larger number of rotations (6 elements with 24 rotations or 12 elements with 6 rotations).

Similar calculations compare the resolution of the 30-element design for baselines of 100, 250, and 500 meters for the same stellar model seen both equator-on and from 40 degrees north latitude. The activity belts and the larger groupings of active regions are visible at the shortest baseline, smaller groupings of plages are resolved at 250 meters, and the full 500 meter baseline is required to clearly resolve the individual active regions.

We will also investigate the possible use of densified-pupil ("hypertelescope") architectures for imaging[16].

V. Enabling Technologies

Stellar Imager will rely on a number of critical technologies, including (those of particular interest to this meeting are shown in italics):

- *precision metrology and formation-flying*
  - 3-level approach envisioned
    - rough formation control via radio frequency (RF) ranging and thrusters (to m's)
    - intermediate formation control (to cm's) via modulated laser ranging
    - fine control of optics (to nm's) via feedback from science data system/phase diversity
  - autonomous nm-level control of mirrors in many-element formations over km's
- *deployment/initial positioning of elements in large formations*
- wavefront sensing and closed-loop control of many-element optical systems
- *coarse ranging and array alignment*
- aspect control to 10's of μarcsecs
- *variable, non-condensing, continuous μ-Newton thrusters*
- light-weight UV quality spherical mirrors with many-km-long radii of curvature
- larger format energy resolving detectors with finer energy resolution (R=100)
- long mission lifetime requirement
- *methodologies for ground-based integration and test of distributed s/c systems*
- mass-production of "mirrorsat" spacecraft

Study of these technologies is ongoing at NASA/GSFC, JPL, various universities, and in industry, and significant leveraging and cross-fertilization will occur across projects, e.g. with JWST and TPF. A series of testbeds are in operation or are under development at GSFC, including the: Wavefront Control Testbed (WCT) to study image-based optical control methods for JWST, Phase Diverse Interferometry Testbed (PDIT) to study extended scene phase diversity optical control with moving array elements, Wide-Field Imaging Interferometry Testbed (WIIT) to study extending the field of Michelson imaging interferometers, and the Fizeau Interferometry Testbed (FIT) to study closed-loop control of an array of elements, as well as assess and refine technical requirements on hardware, control, and imaging algorithms. Further information on FIT is available in 3 papers from the 2004 SPIE meeting[17,18,19], in two IEEE papers[20,21], and on the SI website (see below).

VI. Conclusion

SI is currently included in the far-horizon NASA "Sun-Earth Connection" Roadmap. The mission concept continues to be developed by NASA/GSFC in collaboration with LMATC, BATC, JPL, SAO, NRL, STScI, NRL, UCO, DU, SUNY, Sigma Space, and Seabrook Engineering. Further information on the mission can be found on the web at http://hires.gsfc.nasa.gov/~si, where various science and concept presentations, images are available for download and useful related links can be found. A Laboratory Fizeau Interferometry Testbed (FIT) is being constructed at GSFC and initial GSFC Integrated Mission Design Center (IMDC) studies of the full mission and of Pathfinder concepts have been performed. We continue with architecture and trade/feasibility studies in a "Vision Mission" concept study and plan to test and demonstrate design concepts with FIT. Finally, we plan to gather and utilize additional community input and produce a book summarizing the science and societal motivations for the mission, the technology roadmap, and the most promising architecture options. *We invite you to join us in the definition and realization of this mission*. Please contact K. Carpenter (kgc@stargate.gsfc.nasa.gov) or C. Schrijver (schryver@lmsal.com) with your comments and suggestions.

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